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Title:	Novel Quantum Dot Technology Shows Promise in Simplifying Vehicle and Structural Surface Inspections
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SAME Magazine Article

Next-Gen Tech in July-August

Novel Quantum Dot Technology Shows Promise in Simplifying Vehicle and Structural Surface Inspections

100-200 Word Proposal

A team of researchers from both the Air Force Institute and Technology and Los Alamos National Laboratory are developing a paint that contains a material called quantum dots which can optically measure deformation of a surface. Quantum dots are the same materials used in new QLED television displays; however, they can also be used for a multitude of sensing applications such as deformation. The researchers used a new method of applying an interfacial layer between the quantum dot paint and the surface under investigation to help adhesion in harsh environments. The primary motivation behind this research is to make both quality assurance and maintenance of aircraft easier for the warfighter. The researchers' efforts started in 2019 and are continuing. The technology works by shining a light onto the surface of the paint and the dots will emit back a wavelength of light that relates to the amount of deformation the surface is going through. This has the promise to allow for real-time 2D surface measurements that is more affordable than other 2D surface measurement alternatives.

Their work was noticed by senior leaders in the Air Force's 2021 Spark Tank for its potential to make deformation measurements much easier.

50-word summary statement

Colloidal quantum dots applied as a paint shows promise to be used in next-gen optical deformation (strain) sensors. Initial capabilities can be seen in a recent study published by a team of government researchers. This technology can be used in both military and the commercial industry applications.

<1,400 Word Article

Accelerate change or lose. Imagine sometime in the 2030s a war breaks out and vehicular assets undergoing years of continuous use need to be quickly checked for structural integrity in order to help ensure their safe operation. This future is edging ever closer as a new nanomaterial-based technology has the potential to produce real-time 2D surface maps of an asset's structural health.

Recently, a team of researchers from both the Air Force Institute of Technology (AFIT) and Los Alamos National Laboratory (LANL) published their work in the American Chemical Society's (ACS) Materials & Interfaces journal highlighting their novel work in characterizing the deformation (strain) sensing properties of a polymer paint impregnated with a nanomaterial called colloidal quantum dots (CQDs). These are the same materials used in your QLED television displays but used for sensing strain instead. To adapt CQDs to this technological use case, light is used to excite the dots and the excited dots emit a specific wavelength of color based upon the diameter of the dots themselves. Hence, the word 'quantum' is in 'quantum dots' because their emission wavelength is quantized. They also are known as artificial atoms. What is novel about the researcher's work is that they used an adhesion-enhancing interfacial layer between the paint and the surface to be measured. This allows the paint to be used in realistic environments outside the laboratory. Some of the applications could be aircraft,

ships, ground vehicles, buildings, and bridges. In addition, all the materials employed to bring this technology into reality are commercially available.

The motivation behind the development of the paint came from a need from an Air Force maintainer to help simplify their non-destructive evaluation (NDE) process. During the time, part of the research team was investigating using colloidal quantum dots for fast x-ray detection. However, one of the researchers heard that there is the possibility in which quantum dots could be used to measure strain at a macro scale. After further investigation, it was determined that the dots do change their wavelength of emission with an applied strain. A team was assembled, and a preliminary study was conducted to see if CQDs could be used to sense strain at a macro scale. A primary concern in the study was that the signal-to-noise ratio would be too low to detect any changes using basic equipment. Fortunately, the study was successful and it motivated additional efforts into applying this technology for the warfighter.

Since the quantum dots are applied within a polymer-based paint, they could be used on any surface. In addition, the paint with its interfacial layer is no more than ~20 micrometers thick. This has an advantage towards other NDE technologies that require certain materials to work well. In addition, the thin coating makes it viable for use on platforms that have concerns with weight. Since the paint measures deformation locally, it could be utilized with a rastering (deliberate scanning method) type camera or another method to make a real-time 2D strain surface map. This can be done affordably and is projected to be around 10x less expensive than another 2D strain surface map technology called digital imaging correlation (DIC) when comparing similar spatial resolutions. In addition, DIC requires a painted speckled surface, the use of two cameras which have to be carefully calibrated, and measurements cannot be done in real-time. Spatial resolution of the CQD loaded paint has been demonstrated with the basic setup to be at most 1.34 micrometers. However, the researchers believe the spatial resolution can be improved due to the quantum dots being approximately 10 nanometers or less in diameter. This means nanometer spatial resolution is possible. However, improvements would need to be made to both the excitation and measurement technology. In addition, it has been postulated that this nanomaterial-based strain-sensing paint could be used to detect crack formations by measuring the strain fields occurring around cracks. However, this capability would be further in the future from the strain-surface measurement applications due to the additional research and development needed. In addition to the 2D strain surface map, a camera that can take spatial measurements such as the Microsoft Kinect could be utilized to place a 2D surface map onto a 3D model of the object under test. This would have a lot of use when comparing data over consecutive measurements. In addition, specialists could remotely view how deformation of a vehicle or structure from the data collected from their technicians and possibly through a virtual reality headset.

There are quite a few ways one could use this optical NDE. Since the paint is an epoxy, it could potentially be integrated within composite materials with fiber optics used to both excite and collect the emission of the paint layer. In addition, the paint could be applied on the other side of a material's surface that is optically transparent to its wavelength of emission and optically transparent to the wavelength of light used to excite the paint layer. This would allow the paint to be utilized to measure strain within materials or in hard to access areas.

One must also consider the environmental concerns when it comes to nanomaterials. The most well-established quantum dot material has been cadmium selenide. In fact, the previous work done with quantum dots in addition to not using an interfacial adhesive layer being used for strain sensing may have been unable to go much further than the laboratory due to using cadmium in their studies.

Unfortunately, cadmium is highly toxic and is a known carcinogen. Cadmium is usually used in nanotechnology research due to being well-established and affordable, but newer and safer materials are catching up. Fortunately, less toxic indium-based quantum dots are being sold commercially and were used in the researchers' study.

Looking forward to implementing this technology across a fleet, there are many logistical considerations to process. Generally, once the paint is applied to a structure of interest, a baseline scan would have to be collected. Then, after a regular maintenance interval or when damage is expected, the structure would be scanned again. Any permanent deformation in the structure should demonstrate a measurable change from the baseline. Researchers expect that a crack could be detected by varying the load from the baseline configuration and measuring stress field variations. If a component was repaired or replaced, a new coating of CQD loaded paint would be applied a new baseline would need to be collected on the affected part and the local area surrounding it in order to establish an accurate baseline for future scans.

While operational uses of this paint are still years away, this technology competed in the 2021 Air Force's Spark Tank. For those who have not heard of Spark Tank before, it is similar to the television show Shark Tank, except oriented toward new ideas or proven concepts from the Air Force's own members that can help the Air Force. Senior leaders liked the possibility that the paint could revolutionize NDE across the Department of Defense and it won Top-2 in the inaugural Air Force Material Command's Spark Tank. From there, the idea placed in the Top-15 out of over 300 submissions in the overall Air Force's Spark Tank. The researchers are presently looking to secure funding and industrial partners to complete their next phase of research that will allow them to transition the technology to the warfighters.

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Image 1

Caption: Future concept of a handheld camera scanning for surface deformation of an airframe using the nanomaterial-based strain-sensing paint. As the surface is scanned, a 2D strain-surface map is generated for the technician.

Rendered By: 1st Lt Michael Sherburne

Image 2

Caption: A rendering of a class of nanomaterials called colloidal quantum dots. The inside sphere is what is called the core and the outside sphere is called the shell. The shell layer helps to protect the core from environmental effects and increase the amount of photoluminescence the quantum dot can achieve. Surrounding the shell are polymer chains called ligands which functionalize the quantum dot in various media (examples: water, solvents, polymers, blood, etc.).

Rendered By: 1st Lt Michael Sherburne

Image 3

Caption: Experimental setup testing the nanomaterial-based strain-sensing paint. The paint was applied to a dog-bone structure. Equipment that applied tensile strain on a dog-bone structure was used. Excitation of the paint was done by using a blacklight and the emission from the paint was collected by a collimator that directed light into a fiber. A fiber coupled spectrometer was used to measure the changes in wavelengths.

Rendered By: 1st Lt Michael Sherburne

Image 4

Caption: Possible platforms that could utilize the paint, whether at the warehouse level in testing individual components or the operational platform itself.

Collage Made By: 1st Lt Michael Sherburne

Photos from DoD VI

B-52 Photo By: 1st Lt. Denise C. Guiao-Corpuz

Chinook Photo By: Elena Baladelli

Bradley Photo By: Jerome Aliotta

E-2C Photo By: MC3 Elliot Schaudt

Destroyer By: Mass Communication Specialist 3rd Class Erik Melgar

Image 1

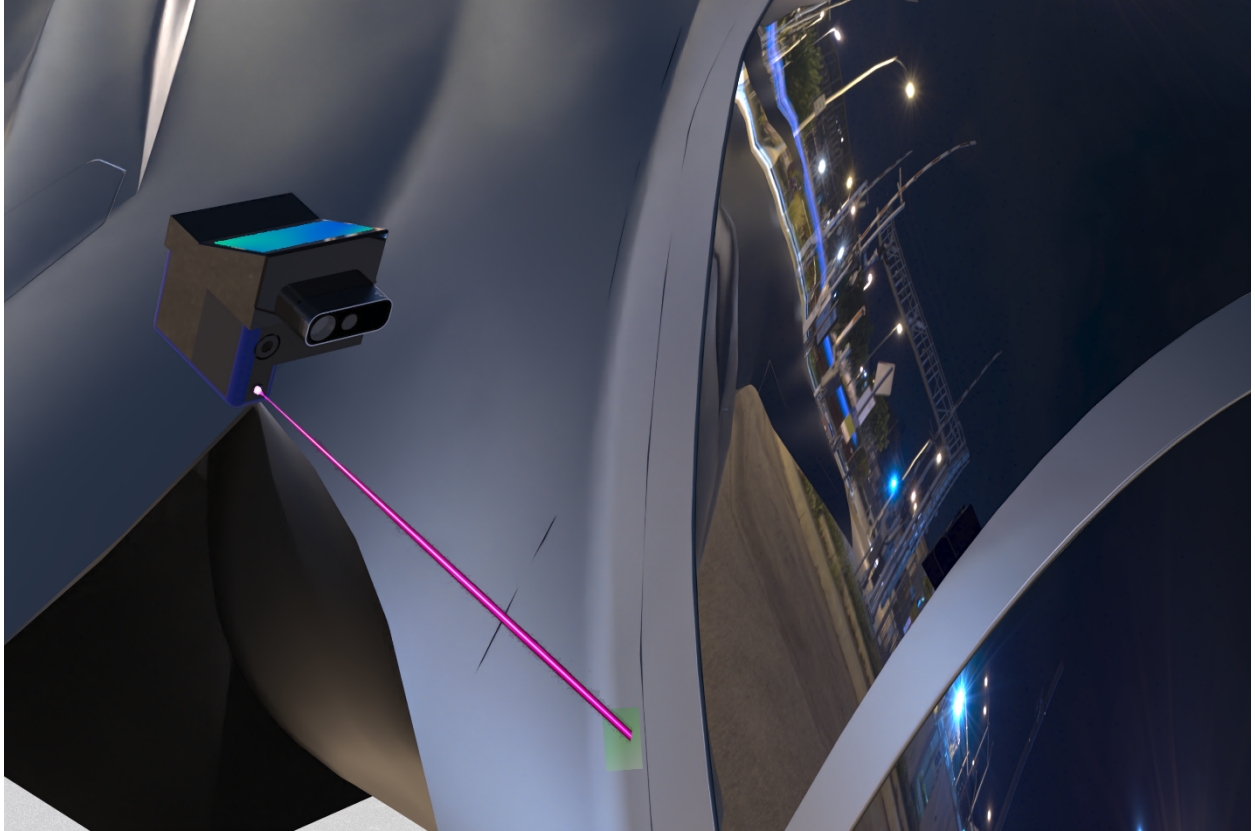


Image 2

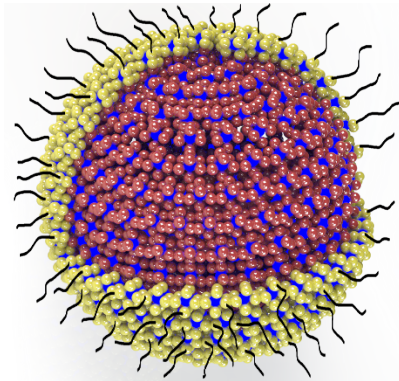


Image 3

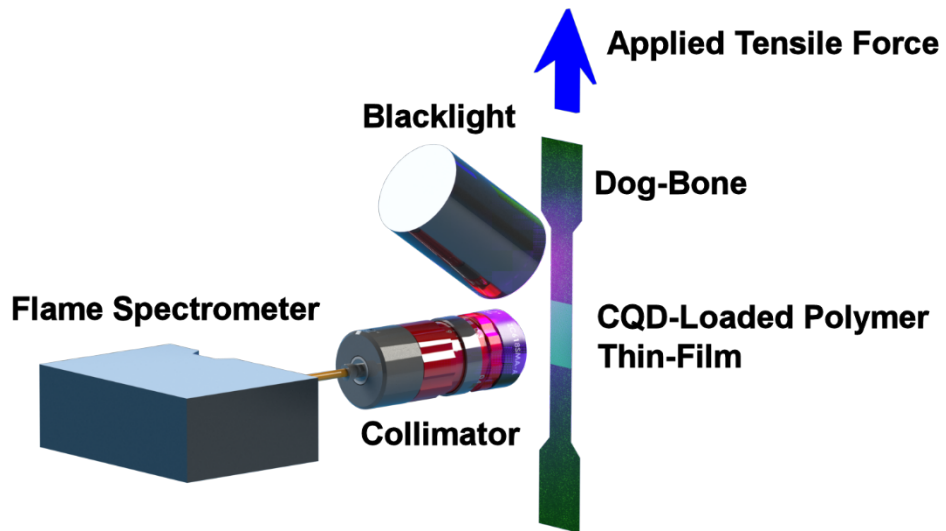


Image 4

